Mereotopological Reasoning in Anatomy

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Abstract: Applications in the field of computer assisted Surgery (e.g. navigation, robotics, simulation) need consistent formal models of anatomical part-whole relationship (mereology) and neighborhood (topology) to enable automated spatial reasoning. We investigated mereotopological theories in terms of their suitability for providing a logical background for such models. The so far results indicate a need for a more spatially motivated classification of anatomical structures to allow a consistent and logic-based mereotopological modelling.

Objective: The long-term objective of our work is to enhance geometric representations of anatomical structures used in model based image analysis and in computer assisted surgery with a logic-based description providing automated spatial reasoning. Looking for a suitable framework for this task reveals the unsatisfactory situation that currently on the one hand a variety of logic based formal mereotopological theories has been described [1,2] and on the other hand some elaborated ontologies based on medical terminology have been developed [3,4] but that the relationship between these approaches has not been investigated yet. Applications of a mereotopological model of anatomy include applications in navigation, robotics, three-dimensional modelling of anatomy, image processing and clinical administration of anatomical data.

Method: The most advanced terminological systems in anatomy are the respective part of the UMLS [4] and its further development, the Digital Anatomist Foundational Model (FM) [3], which provides logical consistence, a high level of granularity and some geometrical, structural and topological knowledge to the UMLS database of anatomy.

These representations can be enhanced by supplying a logical calculus for structural and topological relations like parthood, overlap or connectedness. Based on the theory of General Extensional Mereology [5,6], such mereotopological calculi have been developed in the last decade [1,2]. From our point of view they are very promising tools for modelling the structural and topological aspects of anatomy beyond a terminological level and for providing a sufficient logical background in order to derive strong inferences.

Evaluation Results and Conclusion: Our analysis of different approaches to mereotopology shows that these theories are supplying a consistent logical background for describing anatomy on a geometric and topological level which is independent of standard terminology. We demonstrate these results with concrete modelling examples and inferences that can be drawn, and we outline the relation between the mereotopological approach to modelling anatomy on the one hand and terminology based ontologies on the other hand.

References

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